Accidental Carbon Monoxide Poisoning Due to Domestic Gas Appliances and Gas Refrigerators: The Problem in New York City and Its Control*

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EXPOSURE to carbon monoxide, either as a constituent of raw "manufactured" gas or as a product of incomplete combustion, has been the most common cause of domestic accidental poisoning in New York City. Carbon monoxide poisoning by inhalation of raw illuminating gas has also been the most common cause of suicidal death.

The incidence of these fatalities has diminished considerably. Thus, in 1926 there were 825 accidental deaths from carbon monoxide poisoning in the city,[1] as compared with 222 deaths in this category in 1950. Included in the accidental group were some cases in which the circumstances could not be determined.

The replacement of gas lighting fixtures, the improved design and more rigid standards of inspection, and the testing of new gas appliances by industry have been important factors in reducing the incidence of carbon monoxide poisoning. Nevertheless, the hazard has not been completely eliminated. A large number of defective, worn out, and unsafe gas-burning appliances remain in use and continue to furnish an easy means of accidental poisoning. A serious public health problem still exists and warrants intensive investigation.

The replacement of manufactured gas by natural gas or by mixtures of natural and manufactured gas has mistakenly led to the belief that the danger of poisoning by carbon monoxide has been eliminated because natural gas does not contain any of it. Although inhalation of raw natural gas cannot cause such poisoning, the improper or incomplete combustion of this, as of any other fuel, can result in the production of dangerous amounts of carbon monoxide.

GAS REFRIGERATOR PROBLEM

The problem of domestic carbon monoxide poisoning in New York City has been emphasized in recent years by its increased occurrence as the result of exposure to carbon monoxide generated by incomplete combustion of illuminating gas in the heating units of gas-flame refrigerators. The Office of the Chief Medical Examiner first became aware of such cases in 1937. In that year there were two fatal accidents, each involving a newly married couple found dead at

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home under circumstances at first considered mysterious until the deaths were traced to carbon monoxide produced by a defectively operating gas refrigerator. Since that time such deaths, which at first occurred sporadically, have become more frequent. There has been a total of 28 fatal incidents and 39 deaths from 1944 up to and including the year 1950. The year 1949 showed 10 deaths and the year 1950, 13 deaths, a much higher number than in any previous year since 1944. Thirty of these deaths were the subject of a prior communication.[2]

There have also been many single and multiple nonfatal poisonings in combination with fatal cases and in separate incidents. Thus, in 1950 there was a total of 21 incidents involving 50 people, 13 of whom were found dead, the remaining 37 severely poisoned. Similar fatalities have occurred in Massachusetts[3] and in Cincinnati.[4]

The problem of carbon monoxide poisoning resulting from the operation of the gas refrigerator has several distinguishing features in comparison with other types of gas appliances. Combustion of gas in the heating unit of the refrigerator does not take place in the open air but is confined to a narrow cylindrical metal generator flue, which encloses the flame of a modified Bunsen burner. A spiral twisted metal baffle is suspended with only slight clearance in the upper end of this flue. The heat of the flame is transmitted to the flue and baffle and thus to the surrounding sealed generator, which contains the refrigerant gases. The generator flue is connected with a slightly larger calibered ceramic extension flue, and this in turn with a larger dilution flue, which discharges the products of combustion through an opening in the top of the refrigerator directly into the atmosphere of the room.

If the burner is adjusted so that there is an insufficient supply of primary air or is aligned so that there is impingement of the flame on the metal around the flue opening, or if the gas pressure is not properly maintained (especially if there is over-gassing), or if the flue system becomes obstructed with deposits of carbon or corrosive scale so that a sufficient supply of secondary air cannot be drawn in, there will be incomplete combustion of the gas, with the production of carbon monoxide, which is liberated into the atmosphere of the room. There is often a characteristic unpleasant aldehyde-like odor caused by the other volatile products of incomplete combustion of gas in a defectively operating refrigerator. This odor, when it occurs and is detected, is an important warning sign of the emission of carbon monoxide, which in a pure state is odorless. Other significant danger signs indicating possible production of carbon monoxide are overheating of the cabinet and failure of the apparatus to maintain a refrigerating temperature.

Poisoning by the carbon monoxide component of raw "manufactured" or mixed gas is prevented in the case of the gas refrigerator by the operation of a thermostatically controlled valve which automatically shuts off the supply of raw gas should the flame be extinguished.

Since carbon monoxide production results from incomplete combustion, it will be generated by a defectively operating refrigerator whether the fuel used is natural or manufactured gas or a mixture of both. The production of carbon monoxide in lethal concentrations by the incomplete combustion of natural gas and its mixtures in non-vented or improperly vented space-heaters and other appliances has been investigated by Byers[5] and by others.[6] Drinker[7] states that when natural gas is burned, about twice the amount of air per cubic foot must be supplied, as in the case of manufactured gas.

The users of gas-flame refrigerators are not generally aware that such appliances require periodic adjustments and servicing. This type of refrigerator

has no moving parts and is noiseless. It may be operating in an apparently satisfactory manner, without odor, and with a gas flame of the proper color, and at the same time may be discharging dangerous amounts of carbon monoxide. It is therefore imperative that such equipment be inspected and serviced regularly by a conscientious, competent mechanic. This procedure must include careful scrutiny of the entire heating unit and flue system, with thorough cleaning and necessary adjustment, if serious or fatal carbon monoxide poisoning is to be prevented. A carbon monoxide indicator should always be used to test for the presence of this gas.

The gas refrigerator is a continuously operating mechanism, in which respect it differs from other gas-burning appliances. When incomplete combustion of fuel occurs in the refrigerator heating unit, carbon monoxide is continuously being generated and emitted into the atmosphere of the room.

The first gas-flame refrigerators were water-cooled, and the burners and flues were designed to use manufactured gas, which burns more rapidly and requires less air for proper combustion than natural gas or its mixtures. According to the manufacturer, these appliances cannot burn natural gas, reformed natural gas, or high-heat-value oil gas properly. Because of this fact, the manufacturer of gas refrigerators has recommended that the use of all water-cooled refrigerators be discontinued immediately in areas where there has been a change in the composition of the gas fuel and where the adjustment, inspection, maintenance, and servicing of these appliances are not adequately and conscientiously performed.

Spot surveys of water-cooled refrigerators in New York City now fueled with mixed gas and formerly supplied with manufactured gas have shown that they may constitute a grave hazard. Of 330 water-cooled refrigerators tested and inspected, 156, or 59 per cent, were producing dangerous amounts of carbon monoxide. There were 108 additional refrigerators that were not operating properly, although not producing carbon monoxide at the time of testing. Thus, 80 per cent of the group of 330 were found hazardous.

The water-cooled refrigerator, however, does not constitute the entire problem. Of 745 air-cooled models, 304, or 41 per cent, were operating improperly or were producing dangerous amounts of carbon monoxide. These tests were carried out after the change from manufactured to mixed gas.

It is especially important to determine the extent of the same problem in other cities which are currently converting from manufactured gas to other types. There are at present 147 cities in the United States in which manufactured gas is still in use. The health authorities in these places may also be confronted with the problem of increased danger of poisoning from carbon monoxide produced by the water-cooled gas refrigerator if and when there is conversion from manufactured to other types of gas.

Carbon monoxide poisoning from gas refrigerators is characteristically slow as compared to that caused by most other gas appliances. Improperly operating gas refrigerators may discharge carbon monoxide in concentration ranges up to a thousand or more parts per million (0.1 per cent). With concentrations of carbon monoxide in the atmosphere of 400 to 1,000 p.p.m., a relatively long period of exposure is required to produce poisoning and to cause death.[8] This rate of poisoning is also influenced by the activity of the victim. Any substantial leak of raw illuminating gas which contains up to 30 per cent carbon monoxide will soon produce a concentration of carbon monoxide in a confined atmosphere very much greater than the relatively lower ranges of concentration produced by a refrigerator; with ex-

posure to the higher concentrations, asphyxiation by carbon monoxide is rapidly fatal.

In all of the nonfatal and fatal poisonings from the inhalation of carbon monoxide generated by the defective operation of the gas refrigerator, the symptoms manifest themselves insidiously. With the slow accumulation of carbon monoxide in the blood, the victim usually suffers from headache, a sense of dizziness, and muscular weakness. Even before mental confusion develops, the victim may become nauseated and vomit. Gradually there ensues a state of mental confusion and helplessness which becomes extreme. The victim often staggers about; he may overturn furniture and injure himself on broken utensils, frequently leaving a trail of blood stains. There may be involuntary defecation and urination, with evidence that the victim has attempted to clean the feces from his person and surroundings. Washcloths in a basin filled with soiled water or bath water in the tub soiled with feces have been found in several cases. The surroundings are often in complete disorder and the bodies found sprawled in bizarre positions. In many cases the circumstances often give rise to a suspicion of homicide. In several of the incidents investigated, one or two dead persons were found with other persons who were either unconscious or in a completely confused and helpless state simulating alcoholic intoxication.

In all of the fatalities from acute carbon monoxide poisoning in which the victim was found dead at the scene, a conspicuous finding was the characteristic pink or cherry red post-mortem lividity of carboxyhemoglobin in the skin of the dependent portions of the body. These suggillations are readily distinguishable, because of their color, from ordinary post-mortem lividity. In the dark-skinned races the carboxyhemoglobin lividity may not be discernible, but the carboxyhemoglobin coloration of the blood and internal organs can readily be detected at autopsy. A pink color or flush caused by a large amount of carboxyhemoglobin in the blood is sometimes seen in nonfatal cases but rapidly disappears after the victim has been rescued and removed from the carbon - monoxide - containing atmosphere.

In one example of multiple deaths and nonfatal poisoning from inhalation of carbon monoxide generated by the faulty operation of the heating unit of a gas-flame refrigerator the bodies of a mother and infant were discovered. The father, who with an older child had wandered out of the apartment in a confused state, was at first suspected of homicide. Fatal carbon monoxide poisoning produced by a gas refrigerator in an unventilated alcove was immediately recognized by Dr. T. A. Gonzales, Chief Medical Examiner, who was called to the scene to investigate.

In one early case, a honeymoon couple were found dead in their apartment after not having been heard from for several days. The bizarre position of the bodies was especially significant. The refrigerator, which gave rise to the lethal concentration of carbon monoxide, was found in operation. The burner was lit and apparently in working order.

The following case indicates the importance of prompt servicing when a complaint concerning the operation of a gas refrigerator is made. The victim had notified the building superintendent just before noon on Saturday that something was wrong with her refrigerator. He, in turn, notified the refrigerator serviceman, but not realizing the gravity of the situation, and not detecting an odor, failed to turn off the burner. The woman occupant left the apartment soon after and did not return until 9 o'clock that night. Friends who telephoned her the next day (Sunday) received no answer but assumed that she had gone out.

On Monday morning the refrigerator serviceman first responded to the call but was unable to gain entry into the apartment. The superintendent entered with a passkey, immediately detected a disagreeable odor emanating from the refrigerator, and found the occupant dead in bed and the apartment disarranged. The floor of the kitchen and bathroom was soiled with feces, there was blood on the refrigerator door, and a broken pitcher lay on the floor where the victim had evidently fallen and lacerated her forearm. Tests with the refrigerator in operation disclosed high concentrations of carbon monoxide in the bedroom as well as in the kitchen. As in the other cases, all windows in the apartment were closed.

OTHER HOME GAS APPLIANCES

Early in this study it became evident that the household gas refrigerator danger was responsible for only a small proportion of the total number of accidental carbon monoxide poisonings associated with the use of domestic gas appliances. During the ten year period from 1940 through 1949, there were 2,442 accidental and undetermined fatalities from such poisoning in New York City. The undetermined component of this group may include an occasional suicide and even homicide but the great majority were entirely accidental and therefore avoidable.

A study of the geographical distribution of these 2,442 deaths revealed an unduly high concentration in certain areas of the city, but the reasons were not immediately evident. Several questions promptly arose:

1. Why did Manhattan, with a residental population approximately three-quarters that of Brooklyn, have twice as many carbon monoxide deaths?
2. Why did one critical area, which includes three health districts with a population of about 10 per cent of the city, have more than 40 per cent of the total carbon monoxide deaths of the city?
3. Why were there so few deaths, by comparison, in other areas also suspected of poor housing conditions, overcrowding, and other environmental conditions which would seem conducive to a high incidence of accidental carbon monoxide poisoning?

It was established, by comparing housing conditions in three health center districts comprising the critical area—so designated because more than 40 per cent of the total accidental carbon monoxide deaths of the city occurred there—with those in four other health districts of the city, that the age and condition of the buildings were closely related to the number of accidental gas fatalities. The greatest number of dwelling units more than fifty years old was found in that section of the city in which there was the greatest number of such deaths, namely, the Lower East Side. Conversely, districts with fewer deaths had fewer old dwelling units. The reason for this relationship is that in old buildings the gas piping is frequently clogged, pet cocks often leak gas, and serious variations and fluctuations in gas pressure exist.

TABLE 1

Comparison of Age Distribution of Carbon Monoxide Deaths and New York City Population

Age	*New York City (1940)* *Per cent*	*2,454 Deaths* *Per cent*
Under 14 years	15.9	2.4
15 to 34 years	34.3	8.3
35 to 54 years	34.2	28.0
55 to 64 years	9.3	21.3
65 and over	6.3	40.0

The age distribution of the population also plays a part in accounting for the excessive number of these deaths. Table 1 shows the age distribution of New York City's population as compared with that of the group of 2,454 accidental and undetermined carbon monoxide poisoning cases. Of these deaths, 1,515, or 62 per cent, occurred among

persons who were over 55 years of age.

Among older people there are thousands who are crippled, feeble, and partially or wholly incapacitated. For such persons the defective, improperly operating gas appliance is an even greater hazard than for the normal, healthy, younger person. Many of these older individuals are occupants of single-room dwelling units which contain a cot or bed, a sink or kitchen equipment, a gas space-heater, a gas range, and often a gas refrigerator, all in the same small room. Such aged infirm persons, living alone in such a room and keeping the windows shut to keep themselves warm, are easily poisoned by carbon monoxide from a slight raw gas leak or from incomplete combustion during the operation of a defective gas appliance.

During an inspection of dwelling units in the critical area mentioned above, a total of 243 apartments was visited, and gas ranges were found in 239 of these. Of these 239 gas ranges inspected, 115, or 48 per cent, had broken gas lines or defective valves or were actually leaking raw gas. In this same group of 243 dwellings, 6 gas space-heaters and 32 side-arm gas water heaters were found defective. In 11 of these homes there were leaking gas valves, and in 10 other premises there was inadequate and fluctuating gas pressure. In 29 other apartments in this group there were uncapped hose-end nozzles and unused gas lines which were also uncapped. Gas refrigerators were found in 57 of the 243 apartments, and 39, or 68 per cent of these, were seriously defective and were discharging carbon monoxide. In all, in this group of 243 apartments 247 gas appliances were found in such condition as to be dangerous to life. Any one of the defects noted might have caused serious illness or death.

It has been found that chance factors are constantly operating to limit the occurrence of fatal accidents. The duration of exposure to relatively low concentrations of carbon monoxide may be insufficient. Walking out of the carbon-monoxide-laden atmosphere at occasional intervals interrupts the exposure. An extremely important factor is ventilation. Adequate ventilation dilutes a potentially dangerous concentration to a nontoxic level. With low concentrations of carbon monoxide, ordinary ventilation from an opened window may keep the carbon monoxide level below the danger point. The state of health and the activity of the individual exposed to the lower toxic concentrations of carbon monoxide are also significant.

Individuals at rest are not as rapidly poisoned as those who are moving around or who are otherwise active. In warm weather, open windows undoubtedly save many lives and prevent serious poisoning. The greater the distance separating sleeping and living quarters from gas appliances, the less likelihood there is of serious poisoning by relatively small concentrations of the gas. Habits of sobriety and good domestic management also tend to limit the occurrence of serious incidents.

These are only chance factors. In any potentially hazardous situation in which carbon monoxide is being liberated into the atmosphere of an enclosed space, a fortuitous combination of circumstances may permit serious or fatal poisoning. This is especially true in the case of the gas-flame refrigerator, the operation of which is automatic and is taken for granted by the user.

Table 2 lists the gas appliances responsible for accidental carbon monoxide poisonings in New York City in 1950. The table does not include all cases, information concerning some not being available at this time. A total of 222 fatalities from accidental and undetermined carbon monoxide poisoning was reported by the Office of the Chief Medical Examiner,[1] of which only 113 are recorded in this table.

TABLE 2

Gas Appliances Responsible for Accidental Carbon Monoxide Poisoning in New York City in 1950

Type of Appliance	*No. of Incidents*	*Fatalities*	*Nonfatalities*	*Total No. of Persons*
Gas ranges	93	65	65	130
Gas refrigerators	21	13	37	50
Portable space-heaters	13	7	7	14
Side-arm water heaters	9	4	10	14
Rigid-type supply lines	8	3	9	12
Flexible tubing	3	2	1	3
Gas-fired central heating plant	1	3	1	4
Gas cocks	2	1	1	2
Gas steam radiators	2	1	4	5
Wall fixture	1	1	0	1
Information not available	15	13	7	20
Total	168	113	142	255

THE NEW YORK CITY CONTROL PROGRAM

The medical examiner in the routine performance of his duties not infrequently serves the community in the capacity of a public health officer. Thus, he may be the first to detect and warn of deaths signaling the onset of epidemics of disease or of food or other types of poisoning which are of direct concern to the public health authorities. In fatal cases the medical examiner's law requires that all deaths from poisoning, whether suicidal, homicidal, or accidental, be reported to the Office of the Chief Medical Examiner for investigation and post-mortem examination. The law also requires that the medical examiner go to the scene and examine the undisturbed dead body in its surroundings. Thus, he often is the first to suspect or detect death from carbon monoxide poisoning and is then in a position to set into motion a proper investigation by appropriate agencies, which in this case includes the police and health departments. The practice of promptly notifying the health department in such cases has been well established in New York City.

In the City of New York, the Sanitary Code requires that all poisonings, fatal and nonfatal, including those resulting from the inhalation of poisonous gas, be reported immediately to the health department. The Office of the Chief Medical Examiner, the police department, hospitals, private physicians, and gas utilities which carry out resuscitation may have such information to report. Facilities have been set up in the health department for receiving such reports and for the immediate dispatch of health inspectors to the scene at all times. These investigations have provided valuable basic data for the direction of the control program. In New York City, the process of receiving reports of fatalities has been accelerated so that a joint investigation by the medical examiner and health inspector often begins a half-hour after the bodies have been discovered at the scene.

On May 1, 1951, the carbon monoxide inspection program of the New York City Health Department was intensified and a total of 100 health inspectors assigned to the project. Each inspector was given special training in the examination and detection of defective and improperly operating gas equipment. Each one was provided with a carbon monoxide indicator and other testing equipment. Supervisory personnel of of the health department joined with Brooklyn Union Gas Company officials in giving instruction. This utility also provided excellent demonstration equip-

ment and made its full facilities available for this activity. Specialized training was also given by the Servel Company, manufacturer of gas refrigerators, as part of its current coöperative program carried on with the health department to eliminate gas refrigerator hazards.

Three targets were selected. The first was a group of 94 buildings in each of which there had been from 2 to 6 fatal accidental gas poisonings, and in all a total of 211 deaths since 1940. These deaths were caused by gas appliances other than refrigerators. The second target was the critical area already mentioned, in which 988 accidental carbon monoxide deaths, or 40.5 per cent of the total number of such deaths, had occurred. The third target was the 500,000 gas-flame refrigerators in domestic use in the City of New York. Of these, the 85,000 dangerous water-cooled models have been receiving first attention. The objective was the elimination of all equipment found dangerous and in bad repair.

After four months of the most intensive work, 22,328 apartments were inspected. Altogether, 11,056 gas appliances were found which were leaking raw gas, were otherwise dangerous, or were in bad repair. Of this group, 8,085 were gas ranges and 2,140 were gas refrigerators. The balance of 831 represented other gas appliances. A total of 1,087 of the 11,056 appliances had to be sealed immediately because they were in dangerous condition. Another survey of 1,075 gas refrigerators showed that 568, or 53 per cent, were in bad repair, and of this number half were actually producing carbon monoxide. These statistics do not represent a complete picture of the condition of all gas refrigerators throughout the city, since the great majority of these appliances tested were in the Borough of Manhattan, where conditions of servicing are the poorest. However, this area was deliberately selected for the survey in order to examine the problem of gas refrigerators and other appliances at its very worst.

Two things were accomplished during this four month inspection program. First, the defects in thousands of pieces of equipment were eliminated and many hazardous situations cleared up. In many instances, the inspectors actually found themselves face to face with persons suffering from carbon monoxide poisoning caused by defective appliances. In one instance, it was possible to secure a blood sample from a woman who, as the inspectors suspected, was suffering from carbon monoxide poisoning caused by an improperly operating gas refrigerator; her blood revealed a 16 per cent saturation with carbon monoxide. There is every reason to believe that this case and many other similar ones could have terminated fatally were it not for the inspection work.

The second accomplishment of this inspection program was that it provided a yardstick with which to measure the requirements of the total problem. It is known that there are some 400,000 dwelling units in the City of New York that are more than fifty years old. The tremendous amount of man power and time that was required to inspect the 22,000 units already visited would have to be multiplied twenty times to carry out the inspection of the 400,000 dwellings needed to complete the project. It is obvious that some other technique in addition to selective inspection would have to be devised to accomplish the objective. These new techniques are being developed and will be the subject of a later report.

In addition to investigation of accidents and health inspection, a carbon monoxide prevention and control program must also include an extensive program of health education and cooperation with other agencies. In the City of New York, 1,100,000 copies of a leaflet, "Gas Can Spell Death," printed

in English and in five foreign languages, are being distributed as the first health education feature of the program. To do this work the full resources of the community were organized. This health education work must be supplemented by outside notices. The daily papers perform an excellent service in this respect. In addition, other media, such as magazines, television, radio, and trade journals, also must be utilized fully for health education purposes.

Other agencies, official and semi-official, play an important part in helping to achieve the objectives of the program and should be called upon for assistance. These include the public utilities, the public service commission, gas appliance manufacturers, real estate boards, voluntary agencies, and other units of the health department and city government, as well as those whose work has some bearing on the problem. Such an all-out attack is necessary for an effective program.

CONCLUSIONS

1. Accidental domestic carbon monoxide poisoning from illuminating gas constitutes a serious health problem, notwithstanding the decreased incidence of such cases today as compared with twenty-five years ago.

2. The increasing incidence of single and multiple fatal and nonfatal cases of poisoning from the inhalation of carbon monoxide generated by improperly operating gas-flame refrigerators constitutes a new phase of the domestic carbon monoxide poisoning problem.

3. There is need for an over-all program to combat the conditions which give rise to carbon monoxide poisoning from all gas appliances in the home. Health departments and medical examiners' offices should assume leadership in this serious public health problem. The full resources of all official agencies should be utilized and their coöperation enlisted.

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